MOKELUMNE RIVER SPAWNING HABITAT IMPROVEMENT PROJECT
MONITORING

INTRODUCTION

East Bay Municipal Utility District (EBMUD) initiated an experimental spawning gravel enhancement project in 1990, by placing about 500 cubic yards (cu yds) of suitable-sized gravel in the lower Mokelumne River just below Camanche Dam (Fig. 1). The objective was to enhance existing chinook salmon spawning areas as a means of increasing reproductive success of these fish. In 1992, about 300 cu yds of gravel were placed in the river in the vicinity of Murphy Creek (Fig. 1). Chinook salmon began spawning in the new gravels within 24 months of placement at both sites. Gravel placement has been continued over subsequent years in cooperation with the California Departments of Fish and Game and Parks and Recreation, and the U.S. Fish and Wildlife Service. The projects have typically consisted of placing washed river gravel (1-4 inch diameter) adjacent to or within known spawning areas. In the fall of 1993, 500 cu yds of gravel were placed within the Mokelumne River Day Use Area (MRDUA) (Fig. 1). The following year, the substrate was ripped and another 100 cu yds of gravel were placed at the MRDUA. In the fall of 1996, about 650 cu yds of gravel were placed at three sites (2 at the MRDUA, 1 near Mackville Road). In 1997, 1,500 cu yds of gravel (1-8 inches in diameter) were placed at 3 sites (at the MRDUA, near Mackville Road, and about 1 mile below Mackville Road). All sites have been consistently used by chinook salmon for spawning with steelhead spawning documented at 3 of the sites.

In 1998, 1,200 cu yds were placed at two sites (Sites 1 and 2; Fig. 1), 3,200 cu yds were placed at one site in 1999 (Site 3) and 1,200 cu yds were placed at one site in 2000 (Site 4). The objectives of the project are to provide additional chinook salmon and steelhead spawning gravel within the preferred size range and improve intergravel water quality. To determine the success of the project, the sites enhanced in 1998, 1999 and 2000 were evaluated for salmonid spawning suitability prior to gravel enhancement and immediately after gravel enhancement. In addition, use of the sites by spawning salmonids was measured. Suitability parameters included channel configuration and gradient; substrate size; intergravel permeability, dissolved oxygen content (DO) and temperature; and benthic macroinvertebrate community structure. Use by spawning salmonids was measured by conducting redd surveys. These sites will be reevaluated every three years through 2009.

METHODS

Channel Configuration and Gradient

Channel profiles were developed to determine "as-built"conditions, identify changes in channel configuration over time, and determine the potential project life.

> <u>Sites enhanced in 1998</u> - One 30 m transect was surveyed along the thalweg of the stream at each site to measure depths, velocities, stream gradient and longitudinal substrate profile. Five cross-channel transects were conducted to develop cross-sections of the channel bed at each gravel enhancement site. Elevations were

measured every two feet along each transect as well as at any slope breaks. Immediately after initial gravel placement, the sites were resurveyed to determine "as-built" conditions.

Sites enhanced in 1999, 2000 - A cadestral survey which measured X, Y, and Z coordinates between the channel banks and upstream/downstream of the enhancement site was conducted before and after gravel placement.

Substrate Size

Pebble counts were conducted at three randomly selected transects (100 samples per transect) at each site prior to gravel enhancement and immediately after gravel enhancement (Bauer and Burton 1993). Substrate from pebble counts were categorized into twelve sizes (Vyverberg et al. 1996): <0.80 cm; 0.80 cm; 1.60 cm; 2.22 cm; 3.18 cm; 4.45 cm; 6.35 cm; 8.90 cm; 12.70 cm; 17.78 cm; 25.40 cm; and >25.40 cm.

Intergravel Permeability, Dissolved Oxygen Content and Temperature

Intergravel water quality measurements were taken at three random stations were (3 replicates/sample) at each site prior to, and immediately after gravel enhancement. A modified Terhune Mark VI standpipe was driven into the gravel to measure gravel permeability, dissolved oxygen (DO) and temperature following Barnard and McBain (1994). A vacuum hand pump apparatus was used to collect water samples from the standpipe (Saiki and Martin 1996). Water samples were collected for 20 seconds and volumes were measured. Samples were taken at 15 cm, 30.5 cm, and 46 cm depths to evaluate gravel depth and stratification of compaction and sedimentation within known parameters of Chinook salmon and steelhead spawning. Stream depth and velocity (at 60% of depth) at each sample site were recorded with a portable flowmeter. Ambient DO and stream temperature (15 cm below the surface) as well as intergravel DO and water temperature were recorded with a dissolved oxygen meter.

Macroinvertebrate Production

Three random samples (3 replicates/sample) of benthic macroinvertebrates were taken at each of the sites before and after gravel enhancement and in new and unenhanced gravel after gravel placement (1, 2, 4 and 10 weeks after gravel placement). The collections were made with a modified Hess sampler with 1,050-micron openings. The diameter of the sampler is 34 cm. Samples were collected at each site, consolidated, placed in 250 ml bottles, and preserved with 80 – 85% ethyl alcohol (Harrington 1996).

Benthic macroinvertebrate samples collected before and after gravel enhancement were taxonomically identified and separated into life stage and size classification (Harrington 1996; Baldridge et al. 1987). Macroinvertebrates were identified to the family taxonomic level or the lowest practical level (Merritt and Cummins 1996, Thorp and Covich 1991, and Pennak 1989).

Dry biomass of macroinvertebrates was determined by oven drying selected samples of each taxon at 70^{o} C for 24h to constant (dry) weight and the samples were weighed

(Bowen 1983). Since many of these organisms are extremely small (<0.0001 g), groups of 20 to 50 organisms of a particular taxon from each sample were dried and an average weight calculated for that group.

Redd Surveys

Redd surveys were conducted annually in the lower Mokelumne River from Camanche Dam to Elliott Road from October 1 to June 1. Surveys consisted of three individuals walking or boating down the river (depths to 4 feet) and searching for signs of redd construction. This method has been used in past Mokelumne River spawning surveys and in other rivers and streams (Fritsch 1995, Hartwell 1995, Keefe et al. 1994). Redds were marked and their positions recorded by GPS for inclusion in a GIS database.

Enhancement Gravel Mobility

Tracer rocks were selected randomly from the enhancement gravel, measured, painted, and placed along a transect within each enhancement site. Stream depths and velocities were recorded at each location. Surveys were performed the following year after gravel placement to detect tracer rock movement.

RESULTS

Channel Configuration and Gradient

In 1998, elevation measurements were collected along five evenly spaced transects, perpendicular to stream flow at Sites 1 and 2 (Figures 2 and 3, respectively). Elevation measurements were also measured along the thalweg transect at each site. After gravel placement, each site was resurveyed (Figures 2 and 3)

In 1999 and 2000, a laser-level was used to record contour X,Y,Z coordinates at Sites 3 and 4 (Figures 4 and 5, respectively). This provided a more detailed contour of the sites. After gravel placement, the sites were re-surveyed (Figures 4 and 5).

Substrate Size

Substrate size at all sites tended to shift to larger size categories after gravel placement (Table 1 and Fig. 6). There was an average 12% increase in substrate 6.35 cm and larger at all sites.

Intergravel Permeability, Dissolved Oxygen Content and Temperature

Intergravel permeability, expressed as volume of water extracted per second, increased at all sites at all depths (except for 15 cm depth at site 4 and 46 cm depth at site 1) following gravel placement (Fig. 7). Dissolved oxygen increased at all sites at all depths (except 46 cm depth at site 3 and 15 cm depth at site 4) following gravel placement (Fig. 8). Water temperatures decreased at all sites at all depths (except 15 cm and 46 cm at site 1) following gravel placement (Fig. 9).

Macroinvertebrate Production

Data collected to date suggest that the average number of benthic macroinvertebrates, families of benthic macroinvertebrates and dry biomass of these organisms observed in newly-placed gravel equals or surpasses macroinvertebrates in existing gravel adjacent to enhancement sites (Figures 10 - 12). This indicates that the new gravel is functioning well within the parameters of existing Mokelumne River spawning gravel and will provide important forage for juvenile salmonids as they emerge from the gravel.

Redd Surveys

While chinook salmon have spawned within the areas of enhancement Sites 1 and 2 prior to gravel placement, annual redd surveys since 1990 detected no redds within Sites 3 and 4. Recent surveys indicate all 4 sites have been used by spawning chinook salmon within 3 months of gravel placement (Table 2). To date, no steelhead spawning has been observed at these 4 sites.

Enhancement Gravel Mobility

Movement of spawning gravel of various sizes is presented in Figures 13 - 15. The mean distance downstream 1998 rocks were recovered after 12 months in the river was 1.5 m and 2.9 m in 1999. The mean distance downstream1999 rocks were recovered after 12 months in the river was 1.6 m, with some rocks moving as far as 26 meters in that period of time. There was a direct relationship between stream velocity at the release site and distance tracer rocks moved downstream (Fig. 16).

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Table 1. Percent composition of substrate by size category (Total may not equal 100% due to organic material in samples).

Size (cm)	Site 1 (1998)		Site 2 (1998)		Site 3 (1999)		Site 4 (2000)	
	Pre-Project	Post-Project	Pre-Project	Post-Project	Pre-Project	Post-Project	Pre-Project	Post-Project
<0.8	12.5	5.2	4.3	2.7	11.2	0.0	2.5	3.7
0.8	5.9	6.5	2.3	4.0	3.0	0.0	4.4	6.8
1.6	11.6	7.8	2.0	3.7	4.5	3.5	4.4	7.2
2.2	19.5	16.8	8.5	12.7	9.7	2.2	15.7	10.1
3.2	20.1	17.8	13.4	14.0	10.5	12.5	26.4	11.7
4.5	19.5	19.7	19.6	18.7	12.4	30.0	29.1	15.0
6.4	8.6	11.0	9.2	15.3	15.4	27.8	12.6	17.1
8.9	2.3	6.2	10.1	13.7	13.1	17.9	4.6	13.2
12.7	0.0	3.2	12.4	11.0	16.1	3.2	0.0	11.9
17.8	0.0	1.9	2.0	1.7	1.9	1.3	0.2	1.8
25.4	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
>25.4	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.2

Table 2. Number of fall-run chinook salmnon redds constructed in each enhancement site (Percent of all redds observed in lower Mokelumne River that year). * indicates year of gravel placement.

Year	Site 1	Site 2	Site 3	Site 4
1997	34 (2.6%)	45 (3.4%)	0	0
1998	27 (2.4%)*	46 (4.1%)*	0	0
1999	26 (4.2%)	13 (2.1%)	1 (<1%)*	0
2000	28 (2.8%)	22 (2.2%)	25 (3%)	18 (2%)*

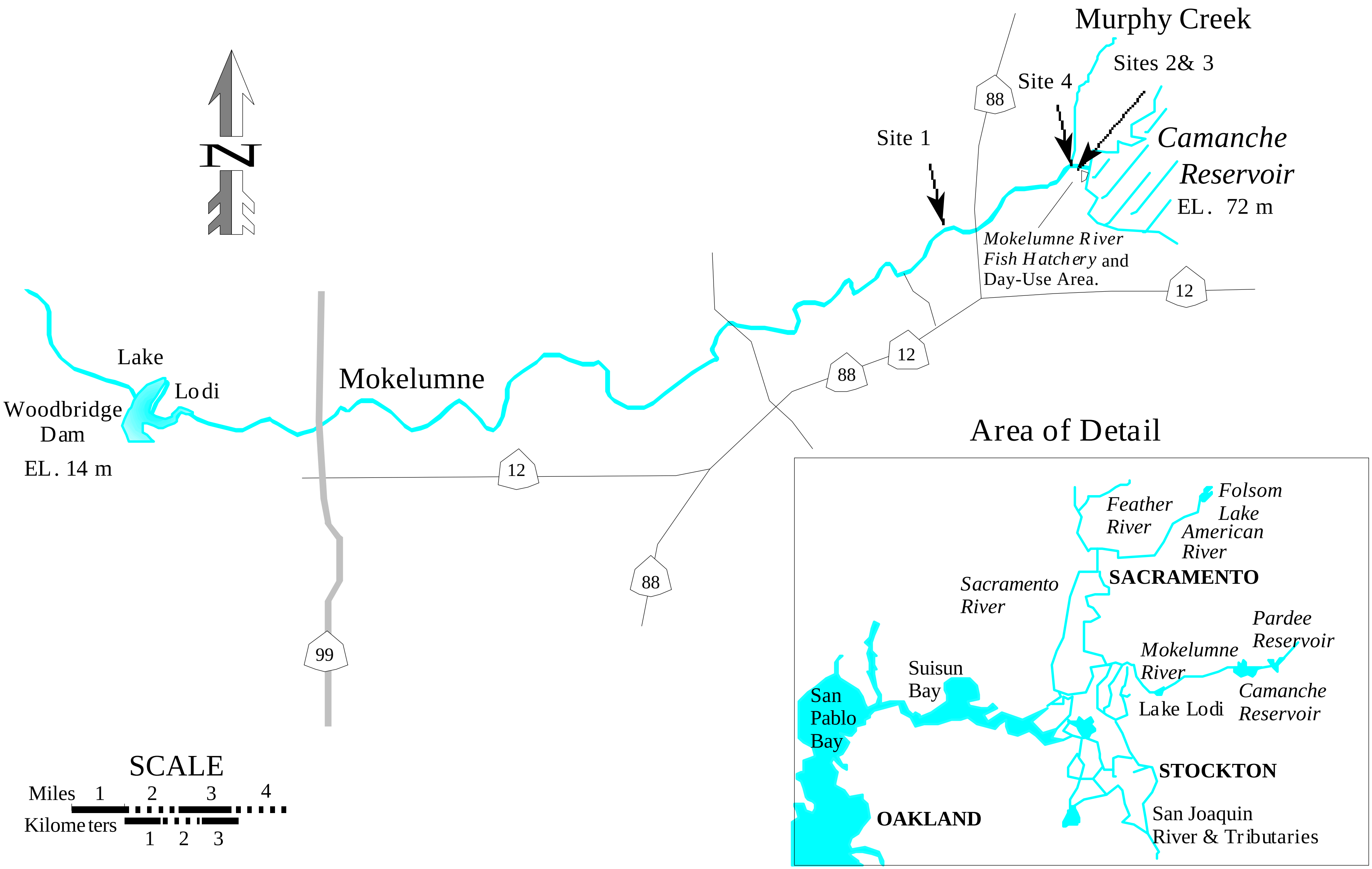


Figure 1. Map of lower Mokelumne River, gravel enhancement sites and associated Sacramento-San Joaquin Delta.

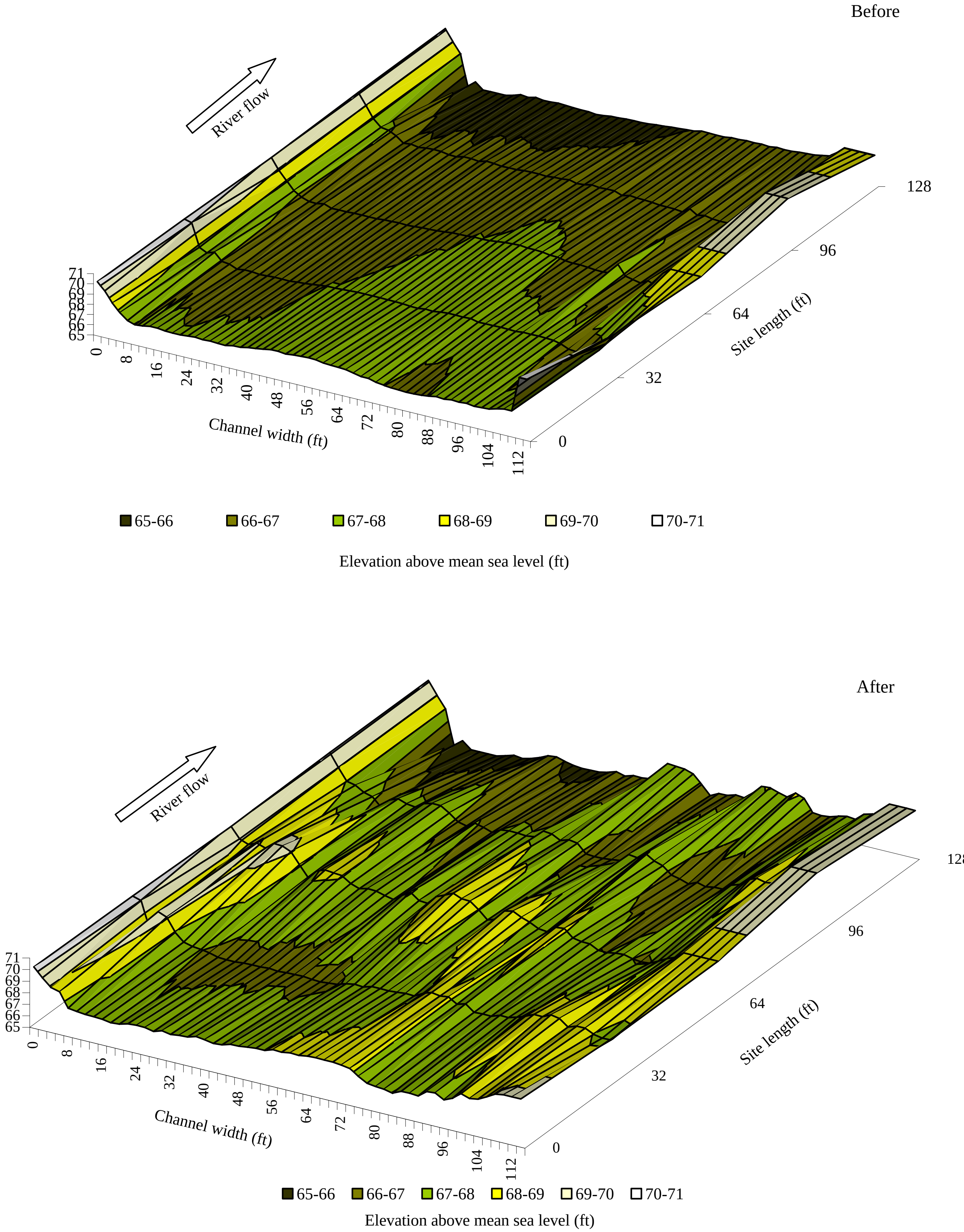
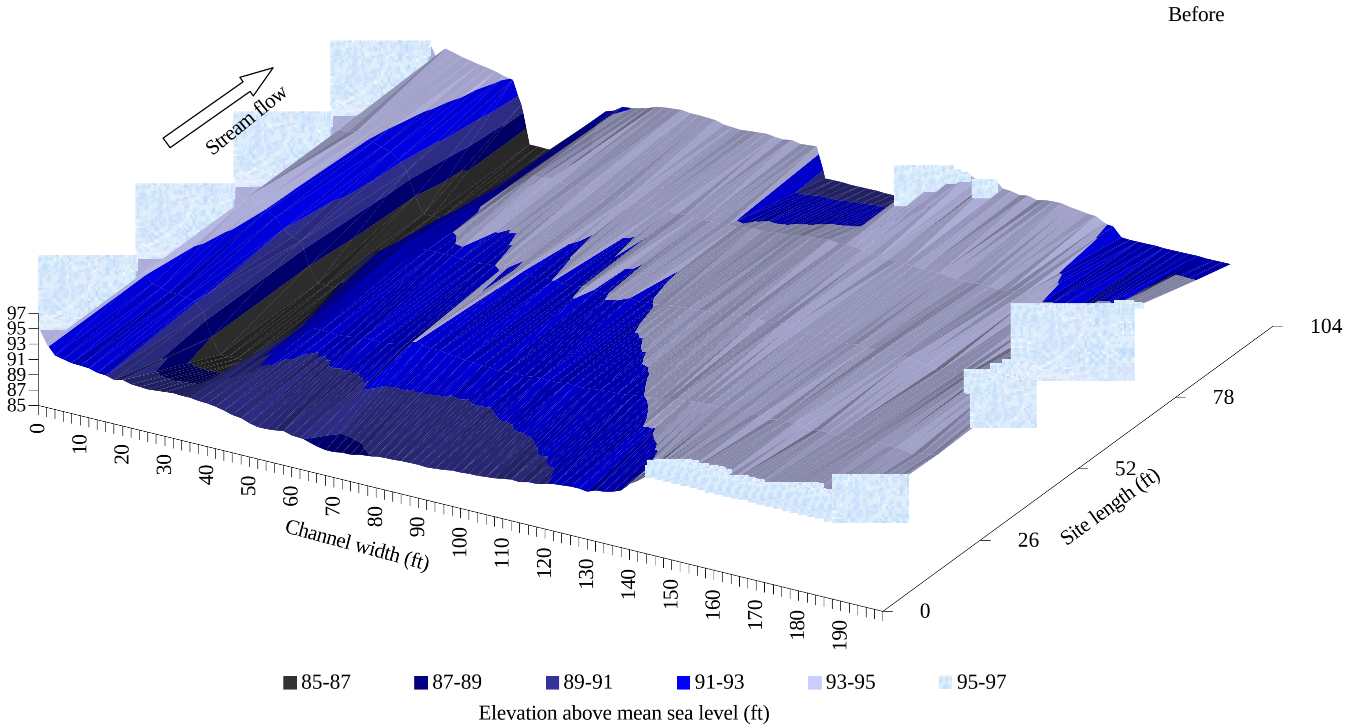


Figure 2. Elevation map of Site 1, before and after gravel placement.



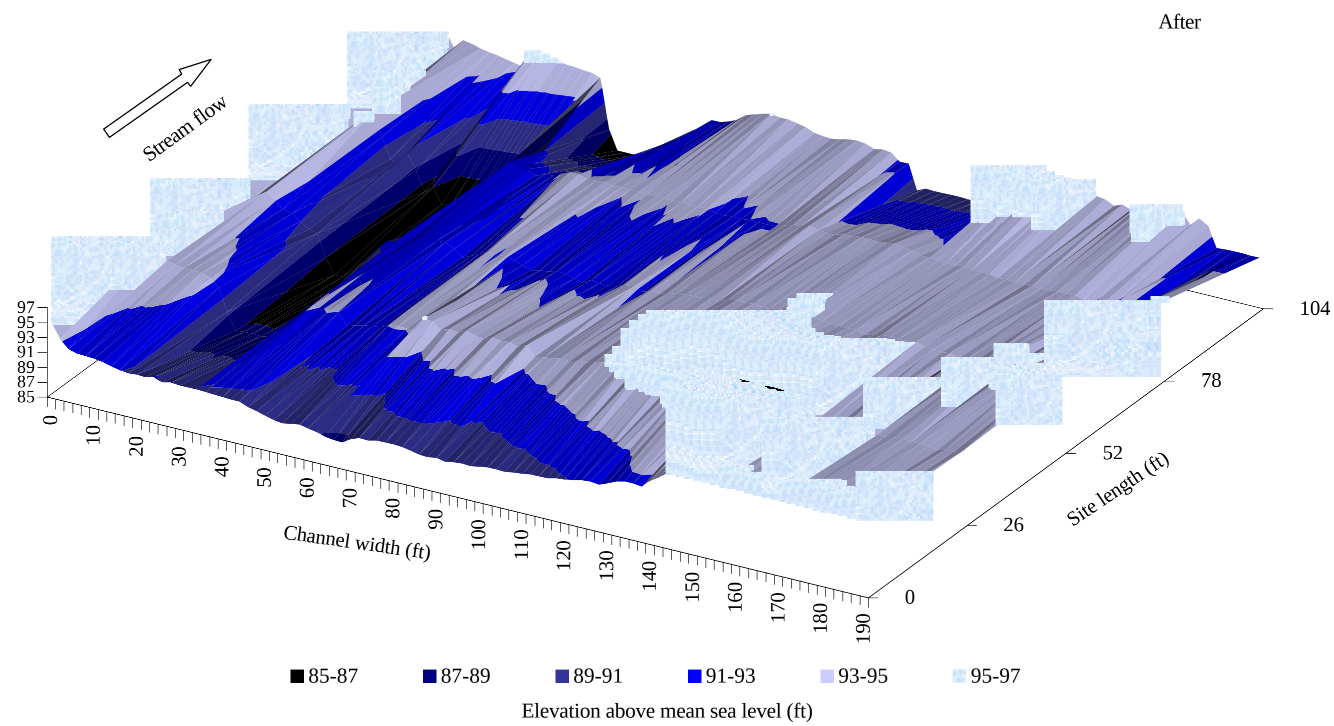


Figure 3. Elevation map of Site 2, before and after gravel placement.

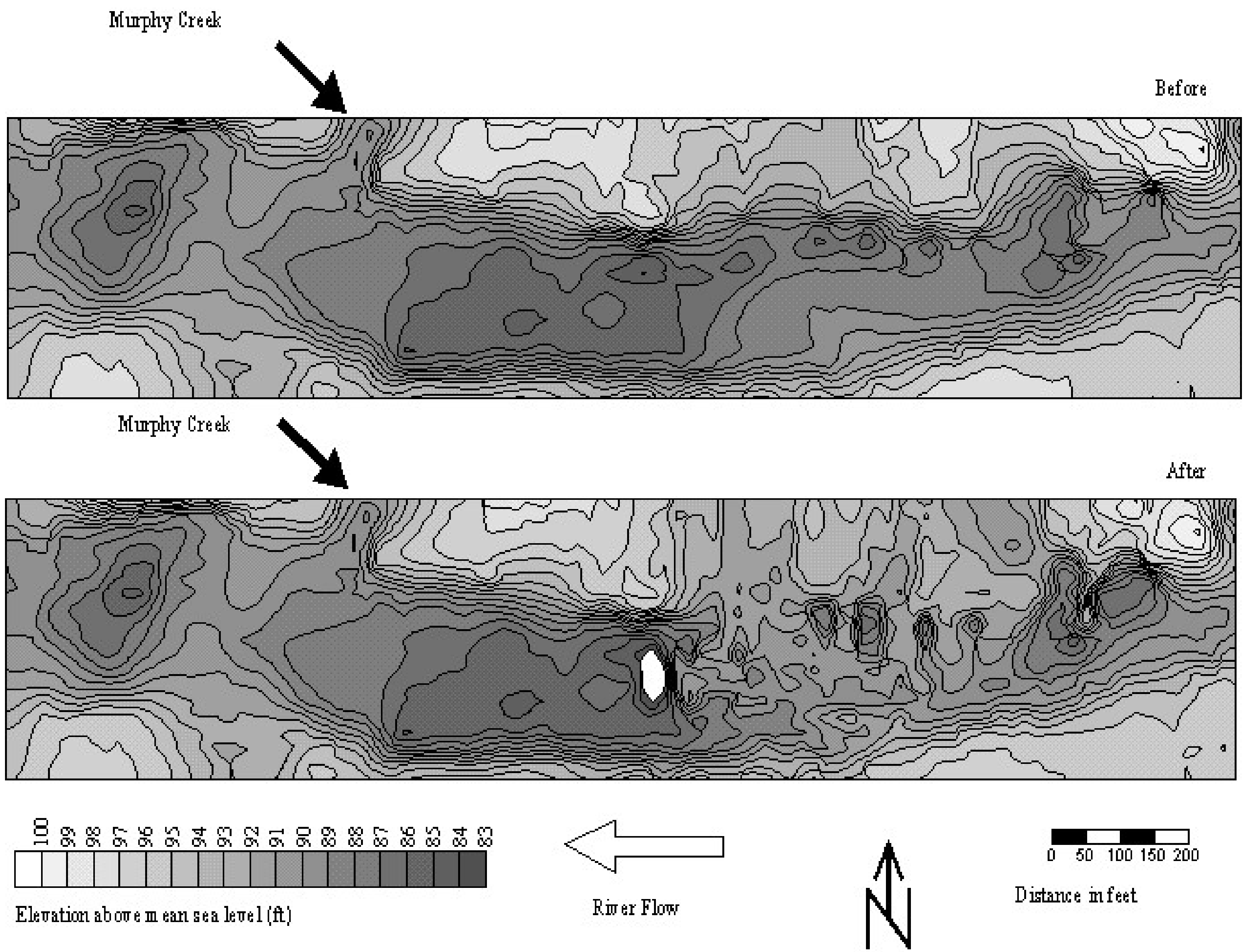


Figure 4. Contour map of Site 3, before and after gravel placement.

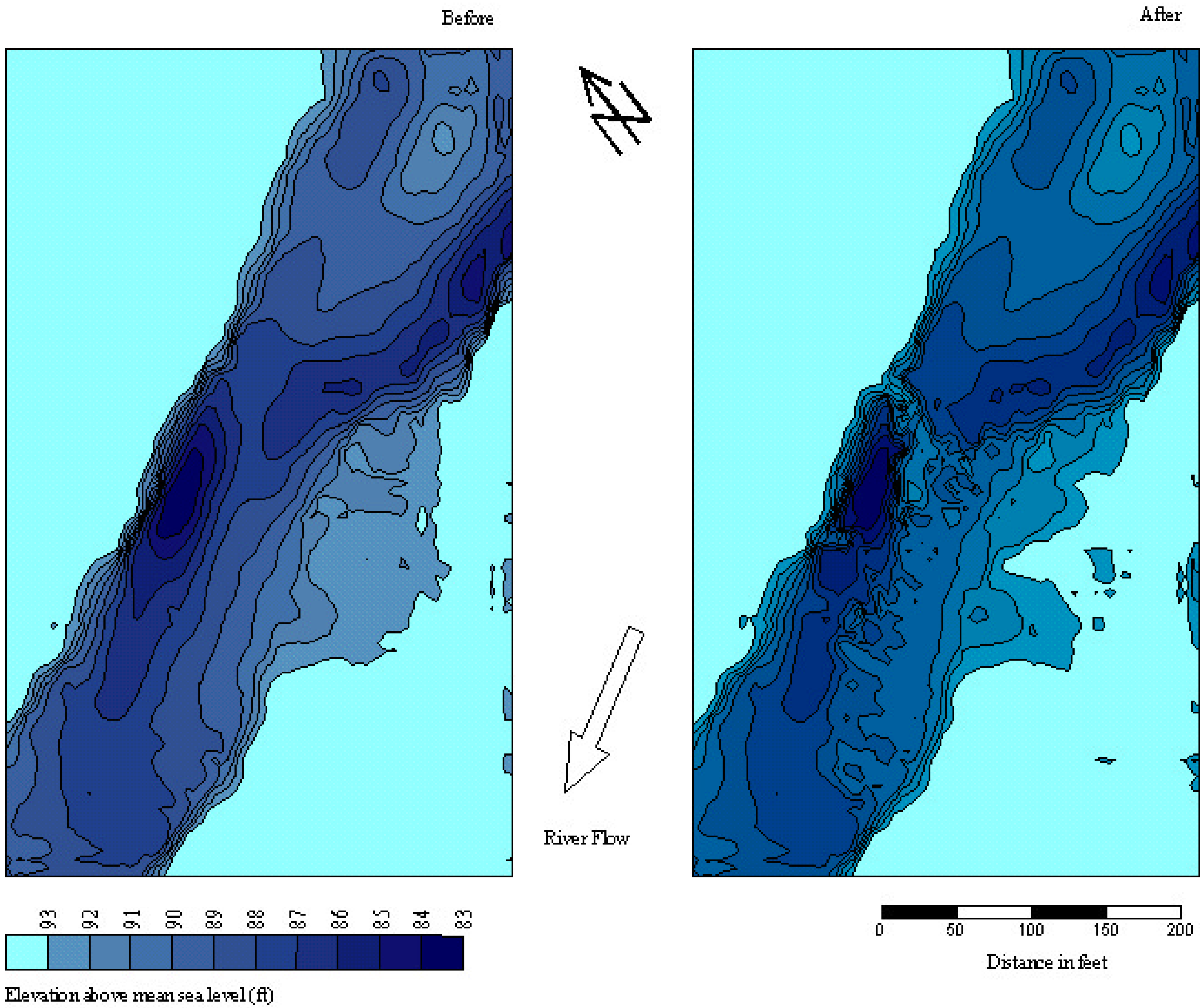


Figure 5. Contour map of Site 4, before and after gravel enhancement.

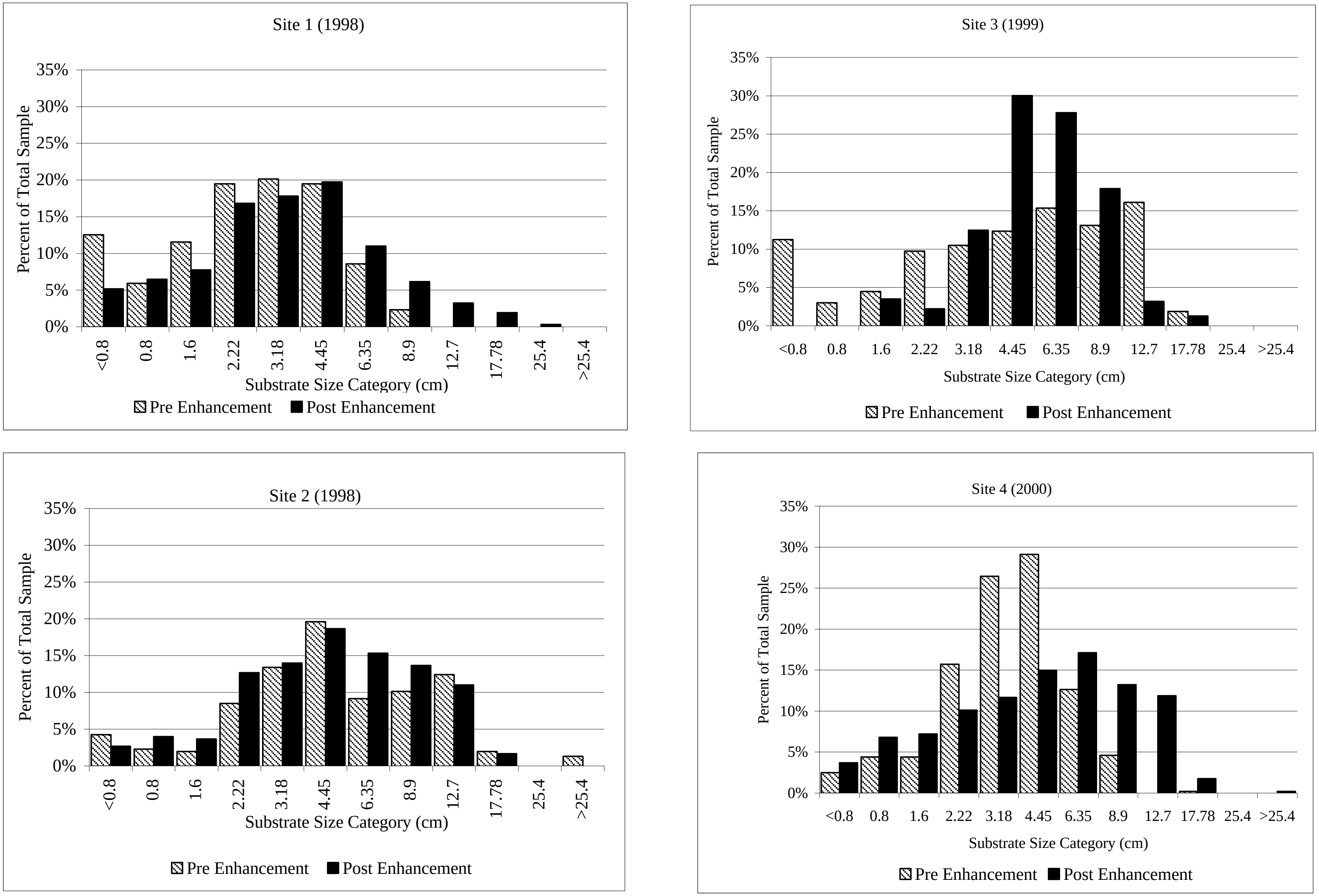


Figure 6. Pebble count survey results from Sites 1 through 4.

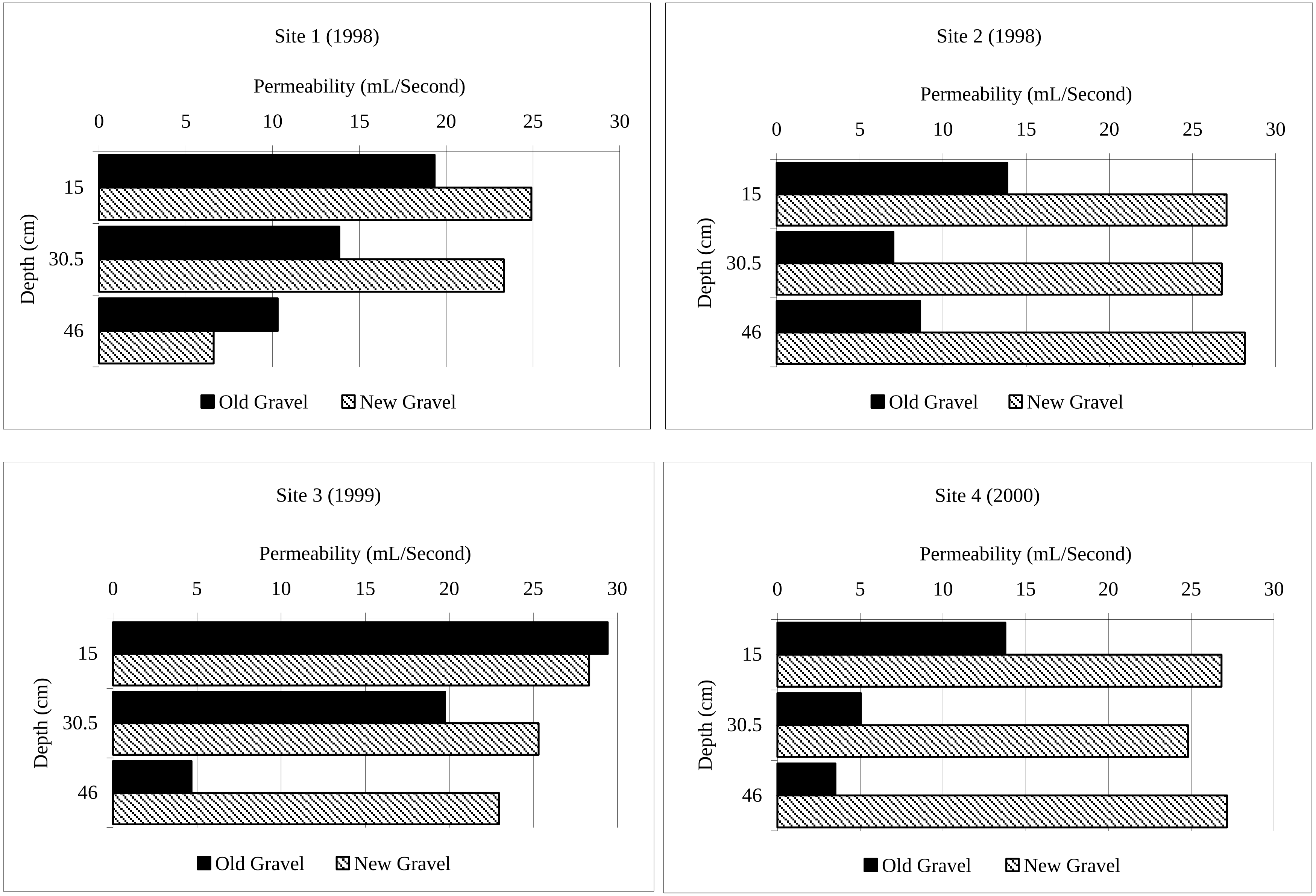


Figure 7. Average intergravel permeability measured at 3 depths in old and new gravel at 4 enhancement sites.

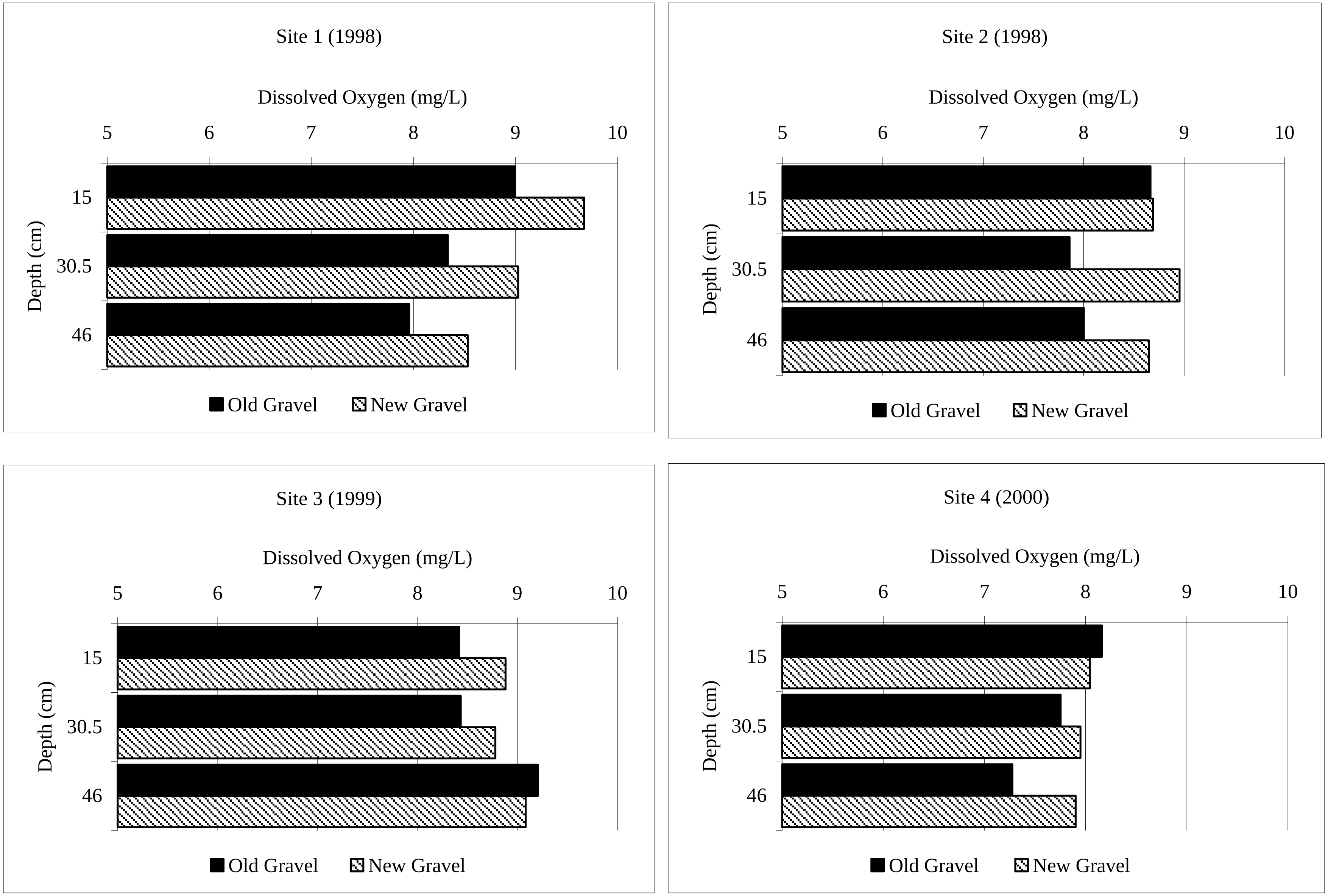


Figure 8. Average intergravel dissolved oxygen measured at 3 depths comparing old and new gravel at 4 enhancement sites.

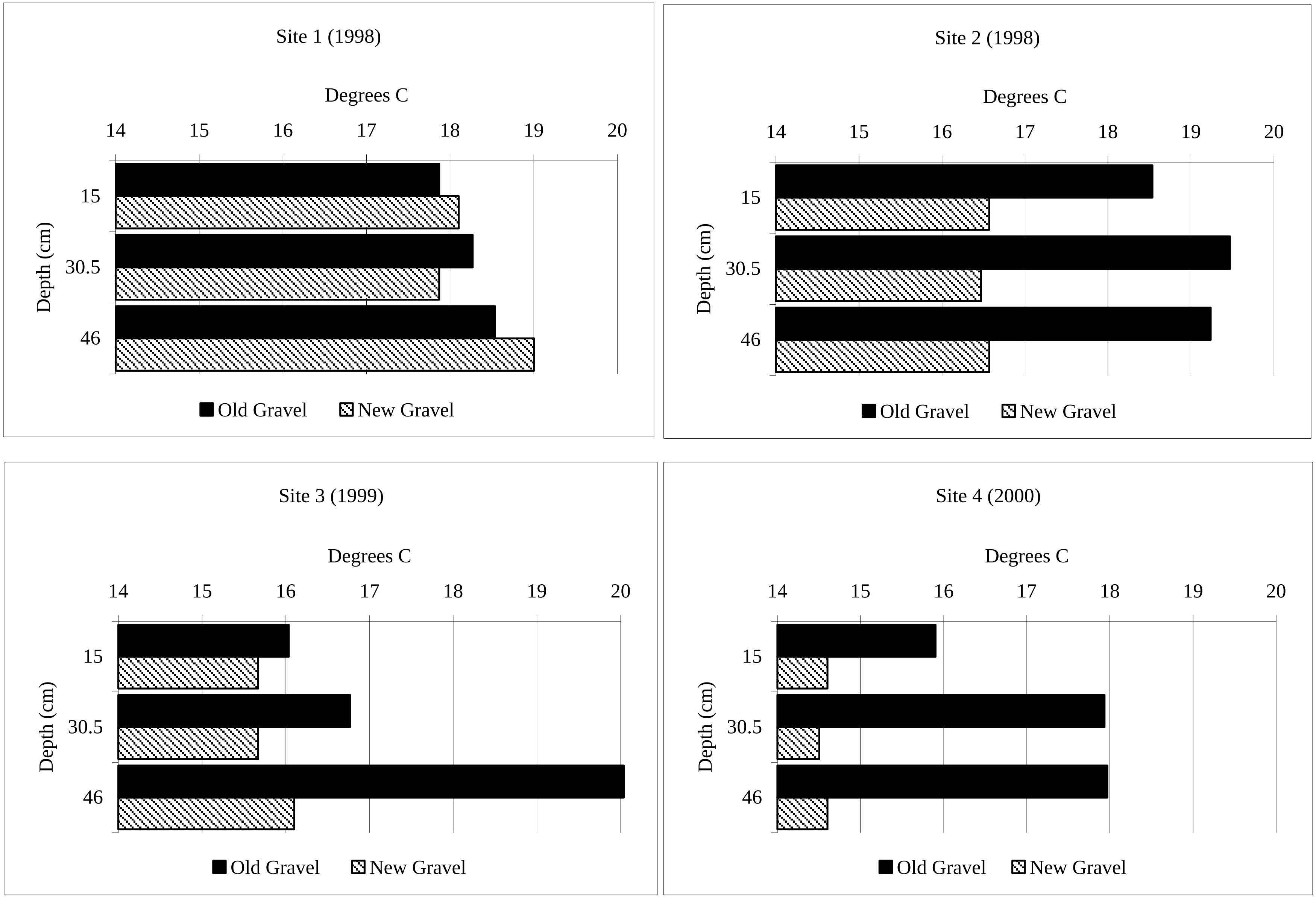


Figure 9. Average intergravel temperature measured at 3 depths in old and new gravel at 4 enhancement sites.

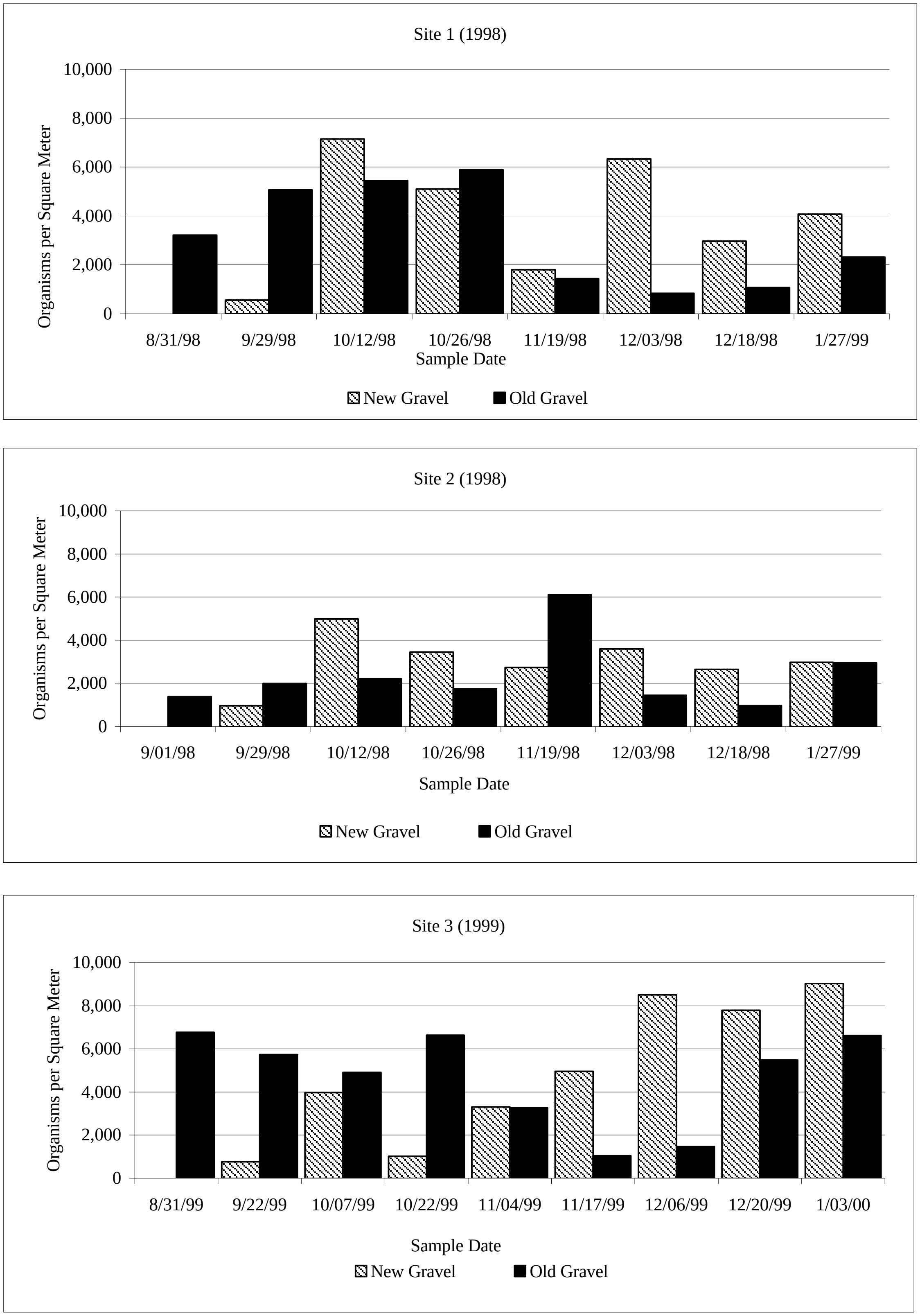
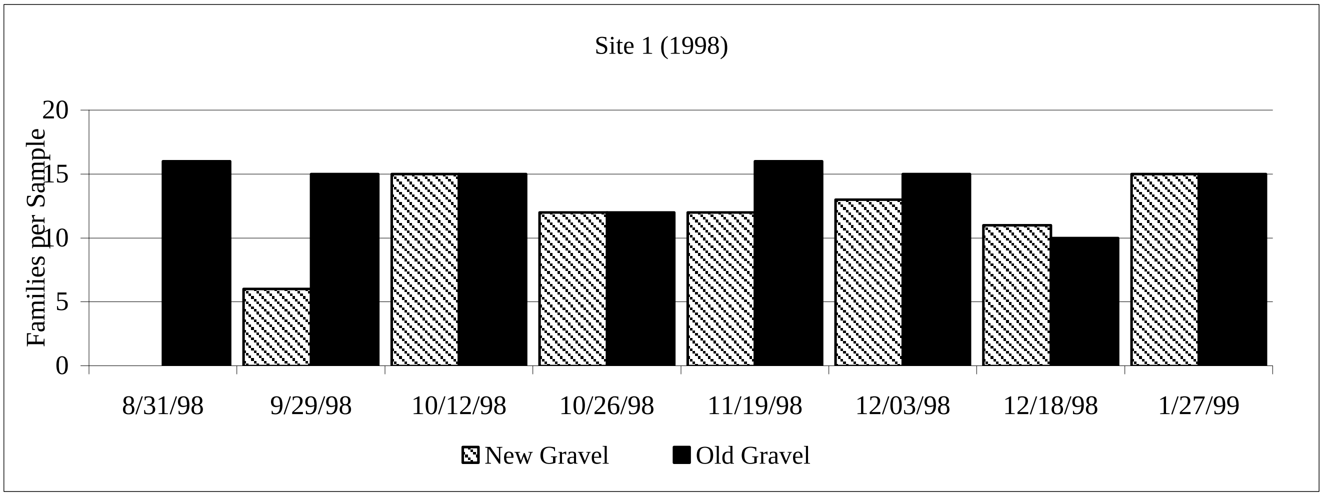
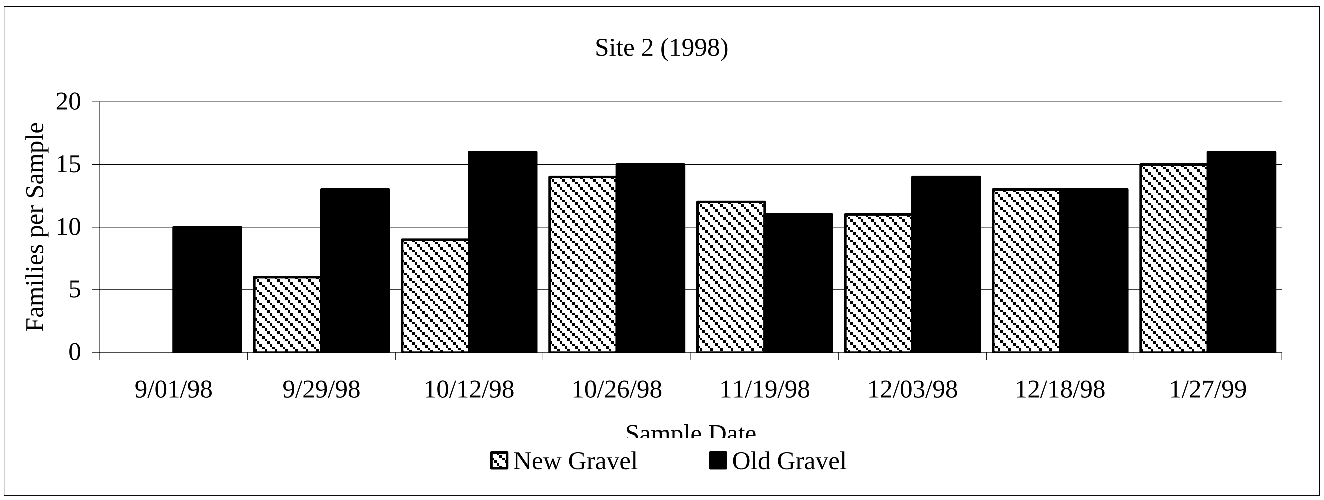


Figure 10. Average number of benthic organisms sampled per square meter in old and new gravel at 3 enhancement sites.





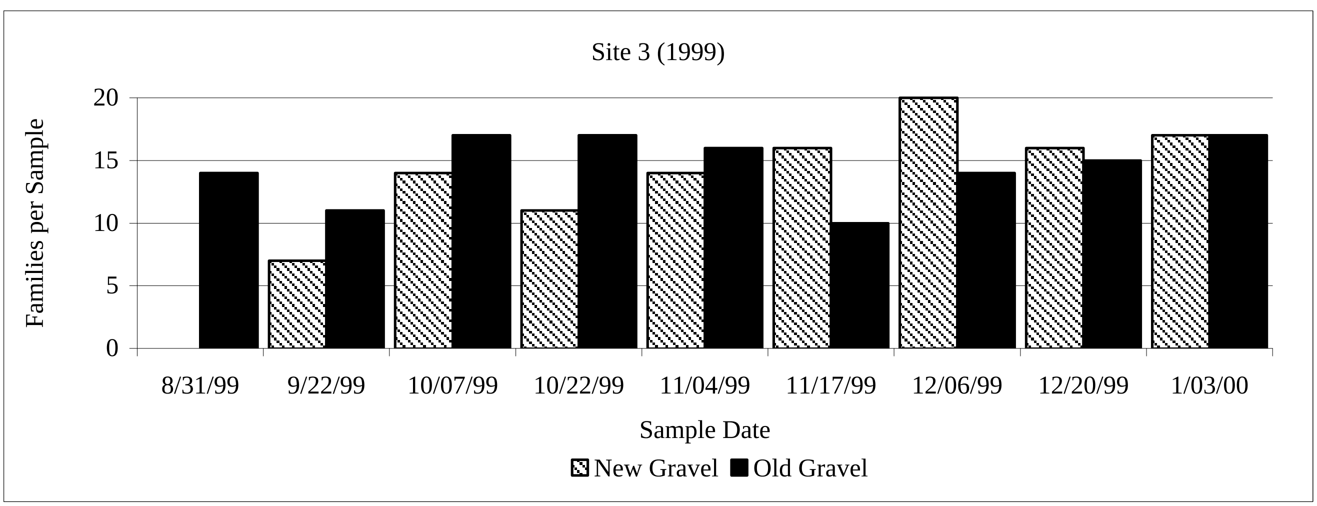


Figure 11. Average number of benthic families observed per sample in old and new gravel at 3 enhancement sites.

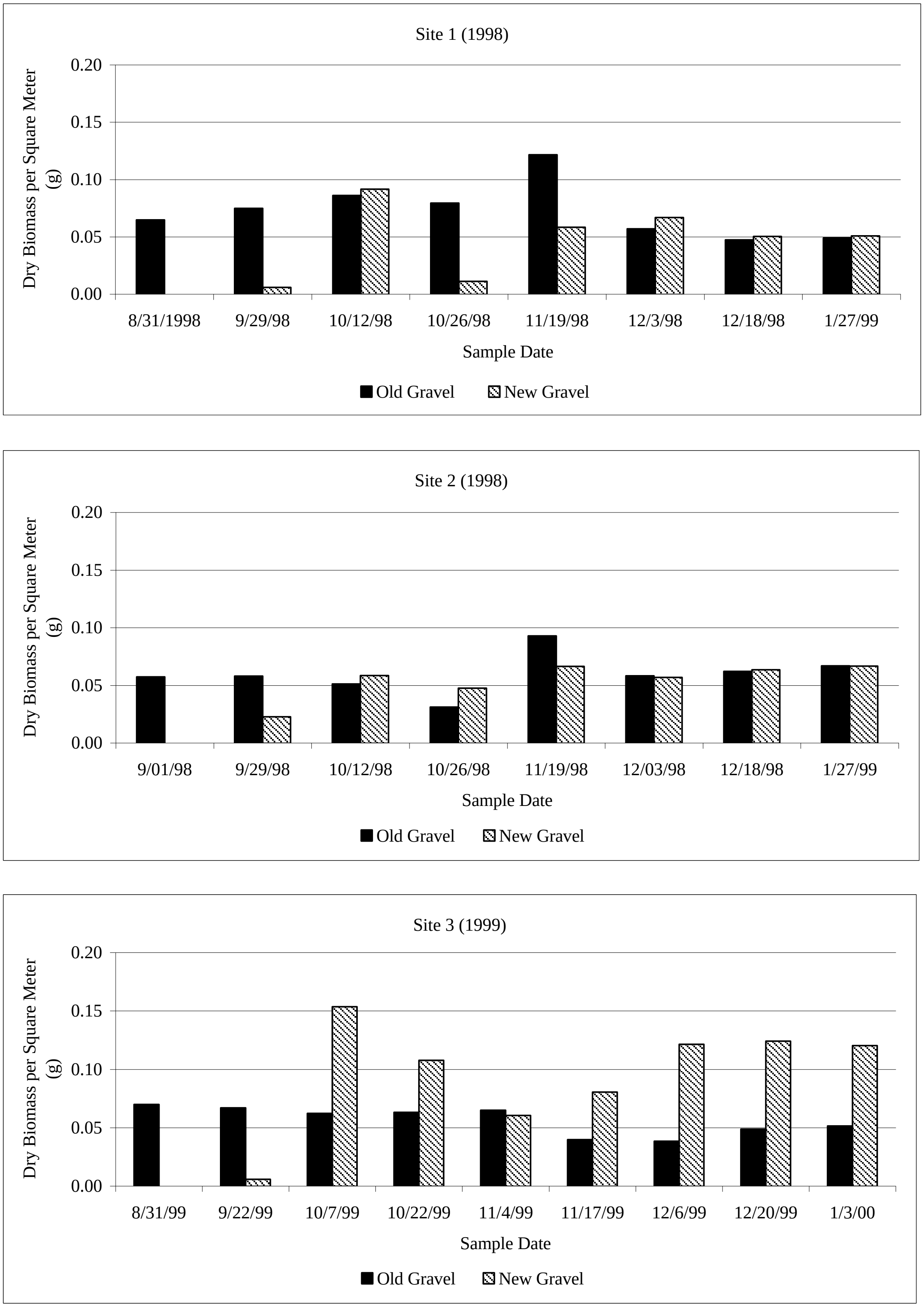


Figure 12. Average dry biomass sampled per square meter in old and new gravel at 3 enhancement sites.

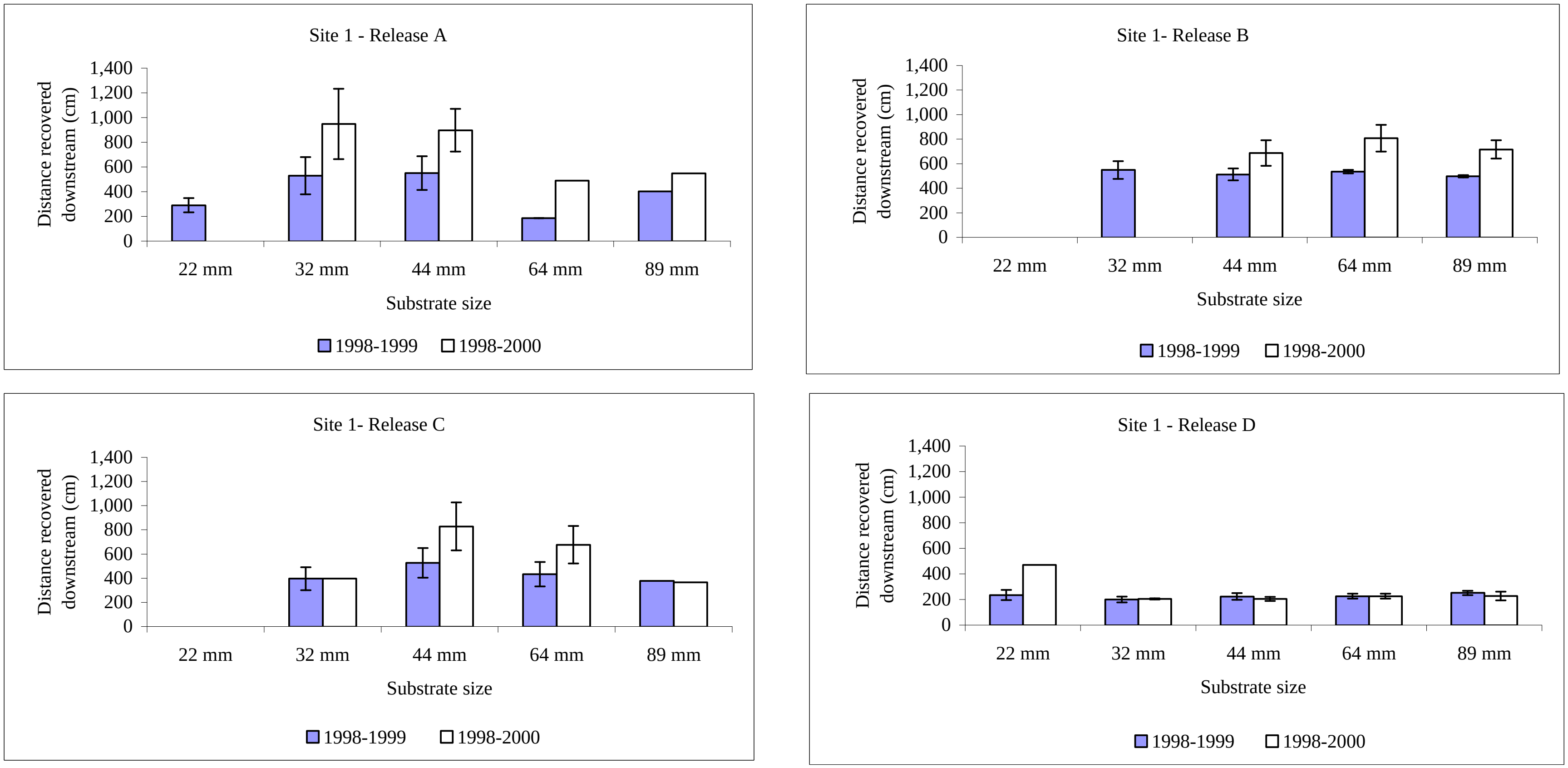


Figure 13. Average distance downstream tracer rocks were found from release Sites A - D at Site 1 after 12 months. Stream velocity at initial release sites were A: 1.02 meters/second; B: 0.81 meters/second; C: 0.77 meters/second; D: 0.27 meters/ second.

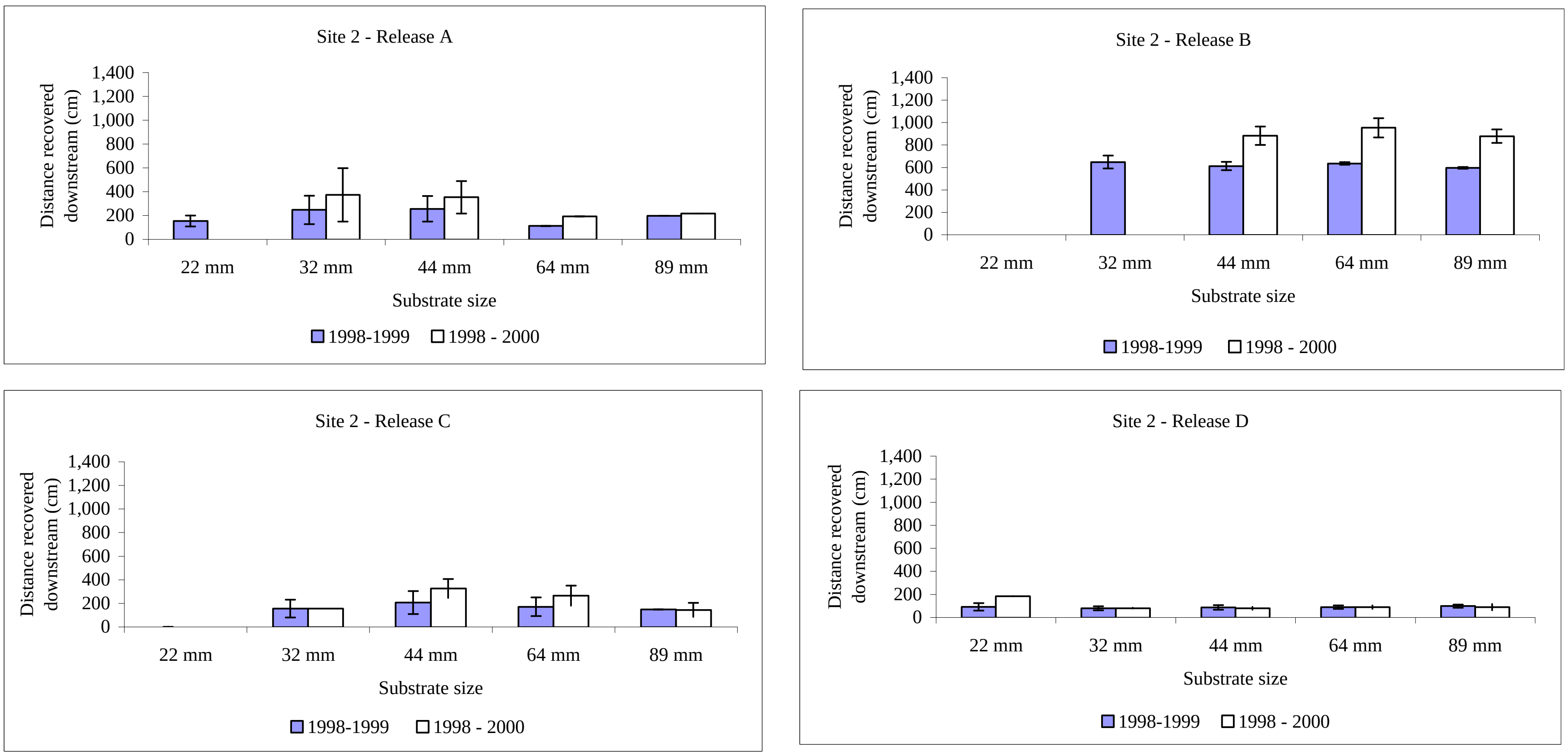
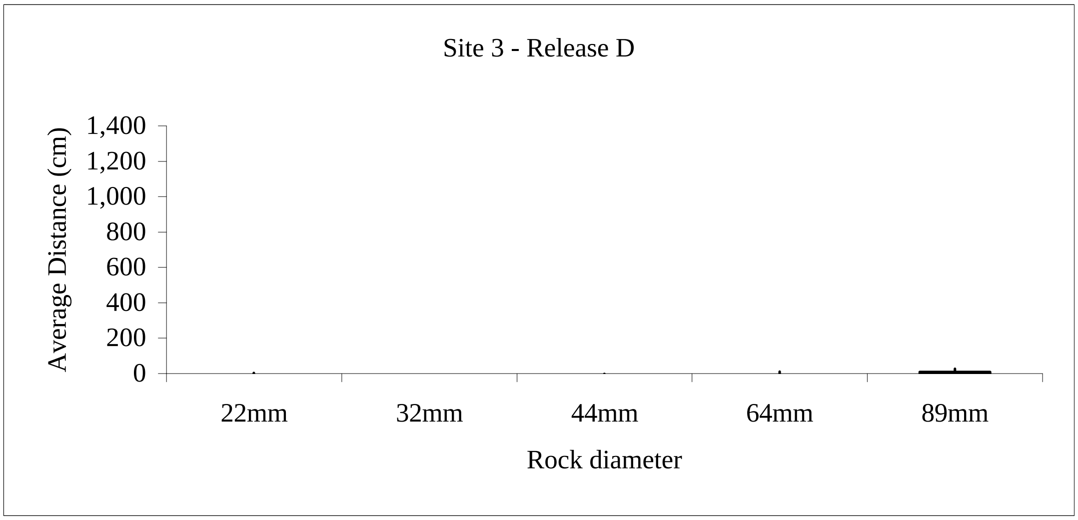


Figure 14. Average distance downstream tracer rocks were found from release Sites A - D at Site 2 after 12 months. Stream velocity at initial release sites were A: 0.75 meters/second; B: 1.21 meters/second; C: 0.68 meters/second; D: 0.32 meters/ second.



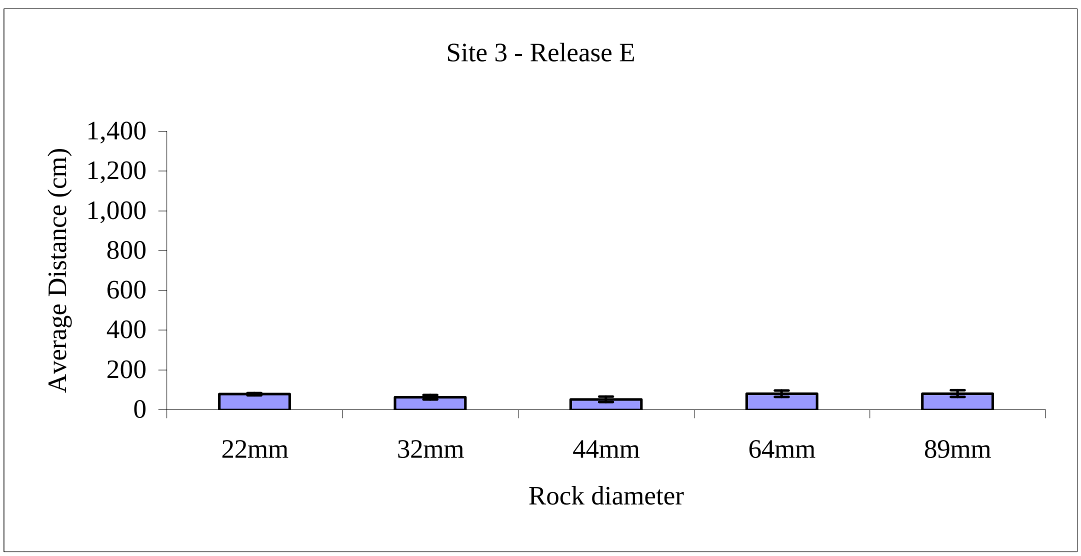


Figure 15b. Average distance downstream tracer rocks were found from release Sites D and E at Site 3 after 12 months. Stream velocity at initial release sites were D: 0.0 meters/ second; and E: 0.50 meters/second.

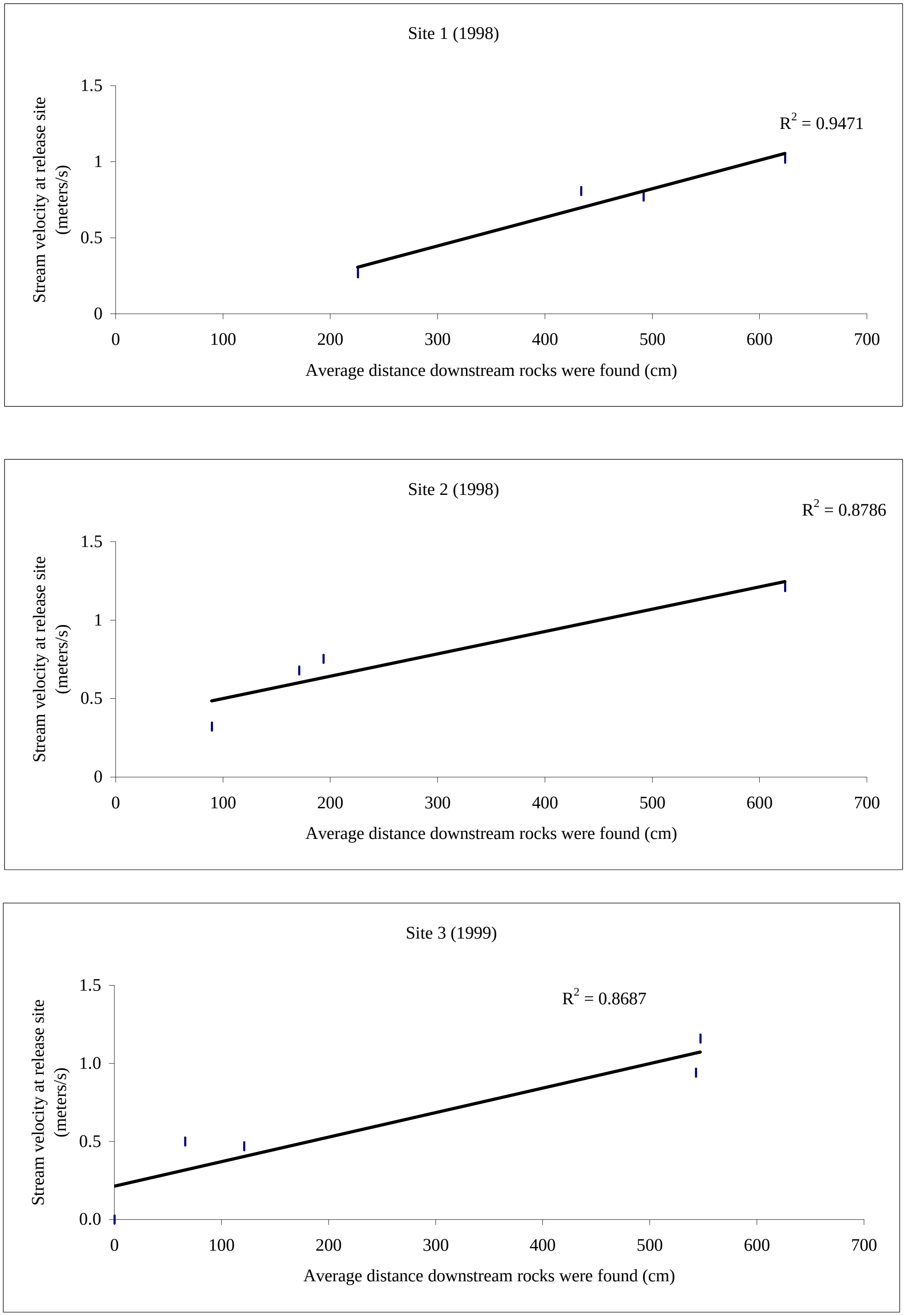


Figure 16. The average distance downstream tracer rocks were recovered from 3 enhancement sites, 12 months after initial release.